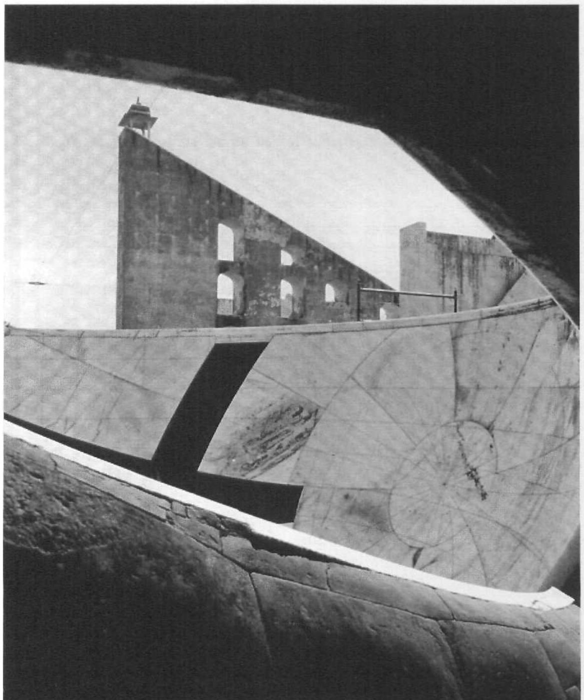
Jantar Mantar

Architecture, Astronomy, and Solar Kingship in Princely India

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The gigantic masonry astronomical instruments built by the Maharaja Jai Singh of Jaipur (1688-1743) are among the most startling and visually compelling monuments in the entire Indian architectural record. As staples on the "must see" list of historians, practitioners, and students of architecture who pass through India these Jantar Mantars, as the observatories are known colloquially, are perhaps second only to the Taj Mahal as perennial attractions. The Swiss architect Le Corbusier mounted a sculptural element drawn from one of the massive instruments atop a hyperbolic cone of his assembly building at Chandigarh (fig. 3), and it seems safe to say that these spare and bold geometric forms, variously described as ultramodern, surreal and mysterious, have stirred interest in the South Asian landscape as no others.

The power of these astronomical instruments to arrest the viewer derives in part from their stylistic departure from the rest of the Indian architectural legacy, especially traditional Hindu forms. Hindu architecture is most closely identified with temples that are cloaked in profuse sculpture with few surfaces left unworked, and the structures at the observatories are stark and unadorned. Programmatically, the works at the observatories are also detached from the architectural record in India whose major buildings include temples, mosques, palaces, and tombs. Prior to Jai Singh's time, observational instruments were not interpreted architecturally either singly or in groups. Astronomers in India, like their counterparts in the Near East and Europe relied on astrolabes and other hand-held instruments of smaller proportions. Indeed, the forms at the observatories are serendipitous finds, like rare birds of paradise, and they are unique in the world. Although there are reports or remains of earlier massive instruments in the Near East or Central Asia, most notably at Samarkand, Jai Singh's designs are for the most part without known formal precedent in India or elsewhere.

The better known and largest of Jai Singh's observatories are easily accessible to the traveler (fig. 4). The most widely visited complex, now meticulously maintained by the Government of India, lies in the heart of New Delhi, the national capital, surrounded by palms in a small park near the Imperial Hotel. A second and even larger complex is located within the palace precincts (once those of Jai Singh himself) at Jaipur, the capital of the modern Indian state of Rajasthan in northwest India, which lies a few hours by rail from New Delhi. Three other similar but smaller complexes were also constructed by Jai Singh elsewhere in northern India-at Benares, Ujjain, and Matura. The last of these is unfortunately no longer extant.[1]

Many casual visitors to the Delhi complex are unaware that the Maharaja Sawai Jai Singh was a man of considerable personal and political ambition who left his signature on an architectural legacy that was even more extensive. His largest project was the design and building of Jaipur (c. 1727), which has served as a regional center from the eighteenth century until the present day. The construction of a new town on such a scale was unprecedented in the annals of Indian town planning. Its design, especially its east-west ceremonial axis and its rectilinear grid pattern, was also remarkable. Formally and conceptually, Jaipur was without parallel in India until the twentieth century, when an international team headed by the Swiss modernist Le Corbusier designed Chandigarh, a new town with which it has often been compared.

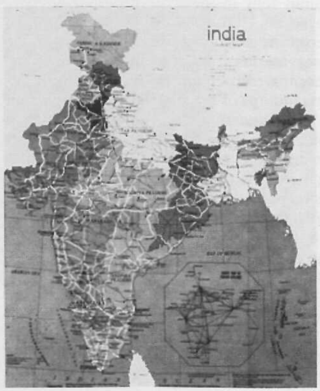
1 Samrat Yantra,Jaipur from the interior of the Jai Prakash Yantra
2 Samrat Yantra,Delhi
3 Palace of Assembly, Chandigarh
4 Map of India showing location of observatories



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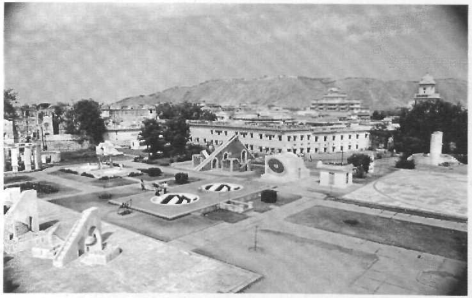
Reading the observatories: the literal level

The astronomical instruments at the observatories are in effect texts that can be read on two different levels, the first literal, and the second broadly allegorical in construction and declamatory in intent. The first reading is derived from Jai Singh's own statements. He left an account of his intentions in the introduction to his well-known astronomical tables, the *Zij Muhammed Shahi.* Jai Singh, he explained (referring to himself in the third person), built the observatories to provide more precise readings of the positions and movements of the known planets, the fixed stars, the sun and the moon, so as to construct almanacs in the service of religion and the state. Then as now in South Asia, astrological considerations were central to all important undertakings from marriages to military maneuvers. Jai Singh built large masonry instruments, he said because experiments with small ones had produced inaccurate readings. Finally he said that Jai Singh had erected the instruments at various locations in North India so that as many astronomers as possible could make their own observations, in the service of science.

The underlying text

Looking beyond considerations of function, composition, or style to areas of underlying meaning, we may discern a social and political intent to this unique architectural program. Examination of other declamatory exercises in which Jai Singh was also engaged will assist us in this reading, as will a generous detour into the public construction of Hindu kingship and the inner workings of Indian culture.

For all their differences, the observatories and the city of Jaipur were ideationally linked. Products of the same fertile imagination, they referred to the same symbolic language and were instrumentalized by Jai Singh as part of a broader political agenda. The Maharaja engaged in a wide range of architectural, ceremonial, and political activities which he orchestrated through a common body of tropes, especially solar allegories, that linked him as a worldly sovereign with the celestial and the divine. He managed to make his own vision of his singular authority other-worldly connections intelligible to his subjects and perhaps to his regional rivals through many redundant tracts. The works at the observatories that projected him as the mastermind of a set of colossal scientific instruments that clocked the heavenly bodies as they along through their paths suggested that his main connections with the universal were empirically or scientifically derived. However, Jai Singh also projected his sovereign authority through celestial allusions that were referentially mythic. For example, he claimed to be descendant from the sun, and he engaged in grandiose sacrifices and ceremonial activities in which he portrayed himself, like the sun or the gods that ensured its eternal return, as an agent of cosmic rejuvenation. In fact, the structures at the observatories embroidered the mythological dimension of the solar narrative, al-



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though the evocative paradigms were inscribed in deft and subtle ways. The instruments not only projected the Maharaja as a "master of time" through the conventional channels of observation and science, but they also were named and troped so as to identify them with the rhetoric of the world-renewing sacrifices through which Jai Singh aligned his worldly authority with that of the gods. The city of Jaipur, which reproduces elements of a cosmic plan with the palace of the Maharaja and his observatory at its very center, enriches this narrative, instrumentalizing themes from Hindu cosmology to project the Maharaja as the worldly counterpart of the divine ruler. It also instrumentalized the tools and precepts of Islamic astronomy to aggrandize his reputation as a divinely inspired scientist.

The major instruments at the observatories

A birds-eye view of the observatory grounds of the largest complex at Jaipur shows approximately a score of masonry instruments of various scales arranged in the park with the palace as a backdrop (fig. 5). At Delhi, the many smaller forms of Jaipur are lacking, and the complex is organized around four instrument types, all of them massive. Unfortunately, precise historical records regarding the development of the observatories from Jai Singh's time to the present were not kept. In fact, modern understandings of Jai Singh's role as a planner and astronomer, and his conduct of rites of state, are drawn largely from legendary reconstructions of the past rather than from state records or contemporaneous eye-witness reports. Although it is not a matter on which the contemporary promotional literature intended primarily for tourists lingers, many of the forms, especially at Jaipur, were actually additions made between the time Jai Singh died in 1743 and the late nineteenth century. Who built them, when, and in what sequence is a historical puzzle that cannot be pieced together completely. Here we shall therefore focus principal attention on three instrument types whose designs are known to be original: the Samrat Yantra (supreme instrument, a sundial) the Jai Prakash Yantra (light of Jai instrument, an armillary sphere) and the Ram Yantra (Rama's instrument) all of which are found at both Jaipur and Delhi, (figs. 6 and 7). The nomenclature of these instruments is of interest and further distinguishes them as a set. Whereas the rest of the instruments are named for their form or function, the names of these three instrument types, all conferred by Jai Singh, are related allegorically to solar rites and themes.

The political setting and the solar lineage of Jai Singh

Jai Singh ascended the throne of the princely state of Amber at the age of eleven in 1699. His kingdom was one of a number of small tributary Hindu states in northern India that owed political allegiance to the Mughals, the Islamic rulers who entered India from Central Asia, governed it from 1526 to 1858, and left an indelible stamp on its literature, architecture, and art. During most of the first two decades of his reign as the Maharaja or 'great ruler' of Amber, Jai Singh was engaged, as his immediate forebearers had been, in military campaigns, sometimes in the service of the Mughal emperors who were seated at Delhi, and sometimes as their foe. Over these years, he consolidated his power in the region, dramatically enlarged the territory under his personal control, ingratiated himself with the imperial authorities, and emerged as an influential spokesman for regional interests at the Delhi court. Beginning around 1720, he turned his attention first to building programs and later to sacrifices that would be the visible expressions of his new found influence and power.

The Kacchawa Rajputs, the family to which Jai Singh belonged, had fully formulated theories about their cosmographic location in the universe as well as about their celestial connections long before they made use of town planning and astronomy to project them. They claimed descent through the

5 Observatory grounds, Jaipur; View from the summit of the Samrat Yantra
6 Observatory,Dehli; View looking southward from Samrat Yantra
7 Samrat Yantra, Jaipur; View from the west


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heroes of Hindu mythology from the sun. They traced their line to Kusha, the son of Lord Rama, the legendary hero of the great Hindu epic the *Ramayana* who, was the quintessential example of the ideal Hindu regent as well as, according to tradition, one of the incarnations of the god Visnu. Since Rama's line was said to extend back to Surya, the sun god, the Kacchawa Rajputs referred to themselves as a solar race. Their illustrious lineage was extolled by the nineteenth-century court poet Krishnadatta in his poem the *Pratap Prakasa*. "*Only the thousand headed Shesha*[2] *or Narada*[3] *can describe the lineage of this race. No poet or pandit is competent to do so,*"[4] he wrote. But, undaunted, he proceeded to trace the Kachhawas through all four of the Hindu ages:

"*The family starts from Brahma,*[5] *Kashyapa*[6] *and the Sun. In Satyayuga,*[7] *Dhundhumara*[8] *and Mandhata*[9] *were cakravartins*[10] *and there was Bhagiratha*[11] *who brought Shri Ganga*[12] *on the earth. In Treta,*[13] *kings Dilipa,*[14] *Raghu,*[15] *Aja*[16] *and Dasharatha*[17] *were born and the family was exalted by the birth of Shri Ramachandra [=Rama] the incarnation of God, who built a bridge over the sea and installed Vibhishana as king of Lanka after killing Ravana.*[18] *King Asivarma and Prashasvata of the Dvapara age are well known in the Puranas. I have given this description in short.*"

Accounts that linked kings with the great heroes of the Hindu epics were common enough in the tributary states of medieval princely India. In fact, the identification of the cosmological order with the political one dates from the ancient Vedic[19] period and is as old as Indo-Aryan civilization in India itself. According to tradition, gods lived in heavenly cities and regulated the moral and temporal order of the universe; monarchs lived in worldly ones and used their political authority to safeguard the social and moral order on earth. From the Vedic period onward, the divine order was linked to the worldly one through ritual, especially through the regenerative action of the sacrifice which enlisted the everlasting order on high in the perpetuation of the state.

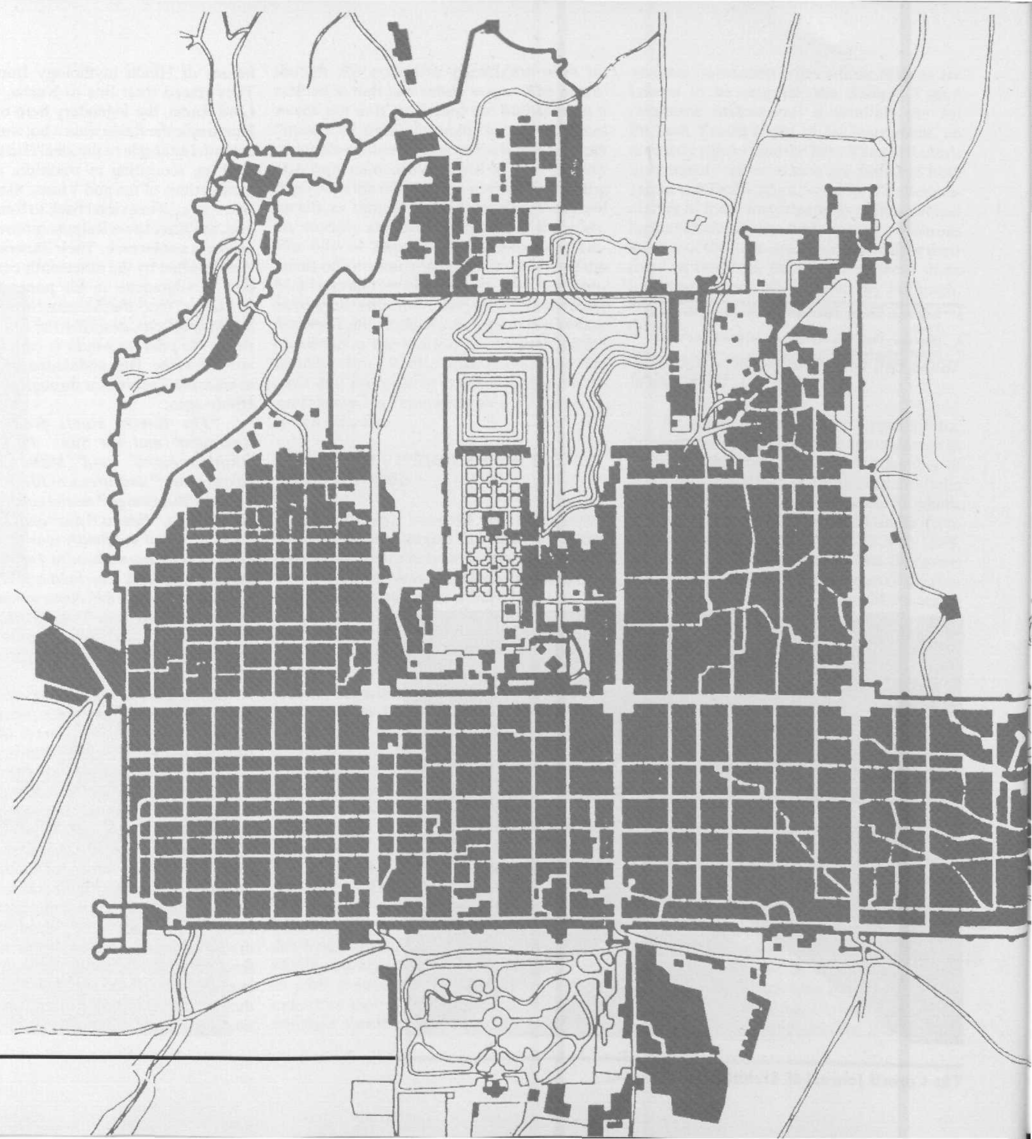
The Hindu cosmological model, town planning, and the 'solar' city of Jaipur

The fusion of the divine order with the sociopolitical one was eventually clarified architecturally in South Asian architecture and planning theory *(silpa sastra)*, which is the subject of a generous body of literature in Sanskrit, the Latin of South Asia and the vehicle of Hindu tradition and liturgy. The formal principles contained in *silpa sastra* were rooted in an ancient tradition of altar building dating from Vedic times, but their development and codification as a science applying to town planning, architecture, and iconography occurred relatively late in the Indian experience (c. 700 A.D. and thereafter), after a major temple-building tradition had begun to emerge. The *silpa sastra* literature, which prescribed geometrical, generally rectilinear formats for major building types and towns, was invested with sacred authority. Its prescriptions were variously believed to be based on other-worldly models revealed by gods to sages or actually composed by divinities such as the architect of the gods, Visvakarma himself. The geometry of the ideal town also expressed certain ideals of rank and hierarchy that were viewed as divinely sanctioned. The rectilinear plan was to support residential areas segregated according to occupation or caste, for example, with the highest-ranking groups in the ritual order given the best and most auspicious locations. In an ordinary town the principal temple was to be placed at the center of the plan, whereas in a fortified capital city, the palace of the king was to be located there. [20] The city of Jaipur is not actually a reproduction of any of the idealized town plans laid down in the *silpa sastra* literature, which are usually composed of concentric rectangles rather that self-contained blocks. However, certain features of its organization show a loose ideational congruence, especially the location of the most important political or ritual complexes at the center. At Jaipur, the palace of the Maharaja is located at the geographical center of the city and a popular temple dedicated to Govinda (Krishna) enclosed within its precincts (fig.8).[21]

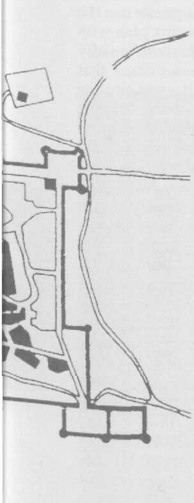
Despite the emphasis on total planning in the *silpa sastras*, communities in India typically grew haphazardly, and this may help to explain why they seldom expressed the ideal geometries executed at smaller scales, especially in the temple plan. In the medieval period, there was only one clear precedent for a 'new town' in north India: the royal enclave of the Mughal emperor Akbar constructed at Fatehpur Sikri in the sixteenth century. It seems very likely that Jai Singh's interest in a holistic urban format as a projection of his sovereign authority may have been stimulated by this imperial example, but a comparison of the plan of Fatehpur Sikri and that of Jaipur shows no congruence. Fatehpur Sikri was essentially a royal citadel, not a holistic urban design, and the axial roadways and the geometry of the neighborhood structure found at Jaipur are completely lacking.

It is precisely because Jai Singh's city seems to have had no clear formal precedent in the landscape of urban India that it has become widely viewed as an exemplary and unique revival of the principles from the *sastras*. The revival of textually sanctioned practices, both of a ritual and architectural nature, was in fact a hallmark of Jai Singh's reign, through which he systematically aligned his kingship with the venerable traditions of the Hindu past. The translation from precept to form, is generally assumed to have been made by Vidyadhar, a Bengali brahmin who served as the chief architect and engineer of the city. Vidyadhar (Bearer of Sacred Knowledge) evidently had broad authority over the development of Jaipur, including the design and execution of the detailed plan, the construction of the palace and other state buildings, and the approval of buildings constructed in the private sector. In a Sanskrit work composed by the court poet Krishna Bhatta in 1749, Vidyadhar is said to have been "well versed in the arts" and to have been held in high esteem for his virtues, which were compared in scope to the ocean.[22] According to the poet, when Jai Singh lay dying, he placed his son and heir in the lap of the architect in the presence of all his ministers.

Otherwise very little is known about Vidyadhar or his relationship with Jai Singh, and in hindsight it is remarkable that his contri-



8 City plan, Jaipur



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bution has been so generously acknowledged. Indian monarchs who embarked on major building programs generally represented themselves as the builders and gave little or no credit to subordinate architects, with the result that the names of very few of them linger in memory. Vidyadhar's embellished reputation, however, permitted the story that Jai Singh wove about his kingship to be embroidered in a particular way. An acknowledged architect invited comparison with the divine craftsman Visvakarma, who according to tradition built palaces and cities for the gods. More specifically, Visvakarma is said to have executed the design of the palace of Indra, the tutelary god of the Indo-Aryans,[23] a figure to whom Jai Singh liked to compare himself. The unusual emphasis on the relationship between the architect and the sovereign thus evoked a familiar divine model. In this way Vidyadhar was instrumentalized so as to align Jai Singh with Indra himself.

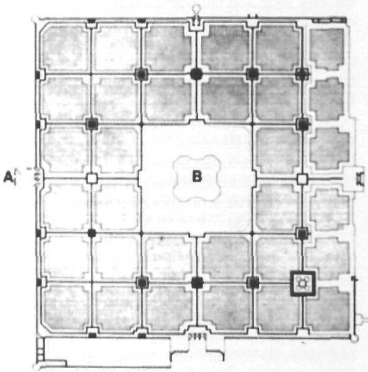
The foundation ceremony for the city of Jaipur took place in 1727, and by the mid-1730s the capital was relocated from its previous location at Amber, the royal citadel developed by Jai Singh's forebears a few miles to the north. As the most elaborate project in Jai Singh's building program, Jaipur became a principal vehicle through which the Maharaja projected the divine antecedents of his singular authority. Three elements of the composition are of special interest: (a) a central solar axis, (b) named gates that allude to celestial paradigms, and (c) a centrally located palace complex.

The Hindu model of the cosmos, widely reproduced on the scale of the temple compound, is walled, quincunx in plan, and oriented to the major and minor directions with the godhead at the center. The *silpa sastras* place a considerable amount of emphasis on the orientation of the site or building so as to align it with the proper directions in space and hence with the cosmic model. All axes are essentially generated from a single line that is drawn by connecting the east and west points of the shadow of the sun cast by a gnomon (in practice, usually a small stick of wood or ivory) that is erected on the site. Some texts also recommend using the Pole Star as a additional marker so as to triangulate the trace of the sun with the celestial north. The perpendicular (north-south) axis is then drawn, a circle inscribed, and angles bisected so as to mark the minor directions. Inasmuch as certain features (rooms in dwellings, or caste quarters in towns, for example) have prescribed directional affiliations, the proper construction of the axes is essential, according to the texts. Altars, ritual diagrams, and the form of the inner sanctum of the Hindu temple are built up on systems of squaring that embody these basic principles of alignment. The association of the perfect square with rites as well as with the inner form of the temple seems to be responsible for the widespread but erroneous belief that the square was also advanced in the *sastras* as the template for the ideal town.[24] In fact, authoritative texts describe the ideal royal city as rectangular.[25]

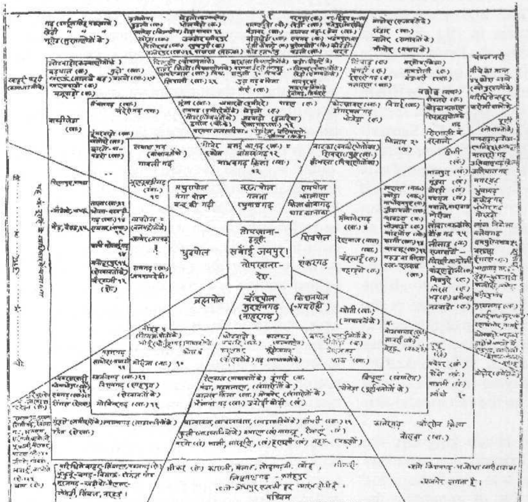
The plan of the city of Jaipur alludes to the anticipated rectilinear outline in a suggestive triangulation, but without completely expressing it. The most important element is the 108-foot-wide axial road running east to west, tracing the path of the sun. It terminates at the eastern wall in a "Sun Gate" and on the west in a "Moon Gate," as shown in (fig. 8). The celestial north is marked by the Druv Pol (Pole Star Gate), which lies off-center in the plan and leads in the general direction of Delhi. In Hindu cosmology, the Pole Star is accorded a special significance because of its 'fixed' (Sanskrit *dhruva)* position. It is often described as shining above Mount Meru, the immovable central axis of the universe—the gnomon of the world as it were, and the home of the gods. The city plan thus reinterprets in plane the triangulation of the three cardinal points that is expressed in reduced scale by the Samrat Yantra, the astronomical instrument that is common to all the observatories, and the largest structure in the complex at Jaipur. The gnomon of this instrument is a triangular form whose hypotenuse slopes to the celestial north. It is flanked by giant winged quadrants lying in the east-west plane, parallel at Jaipur to the ceremonial axis of the city.

In the traditions of Hindu kingship, the fundamental directional triangulation expressed architecturally at Jaipur was also interpreted ritually. In the Vedic rite of upholding the kingdom (the *rastrabhrt* ceremony), the term 'fixed' *(dhruva),* which otherwise referred to the Pole Star and the stable north, referred to oblations intended to 'steady' the state. The oblations were made into the fire over the wheel of a chariot, an iconographic representation of the sun, cyclic renewal, and kingship.[26] The fixed north and the east-west path of the course of the sun that are triangulated and made visible in the Jaipur city plan were thus instrumentalized metaphorically in the sovereign rites. Like other Indian cities that have grown up over time, Jaipur is historically layered and thus a formal collage. There are four other gates (for a total of seven) placed at irregular positions in the city walls, but none of the others belongs to the celestial paradigm.[27]

At the rough geographic center of the city immediately to the north of the east-west axis lies the block that encloses the palace of the Maharaja, the temple of Govinda, and the observatory grounds. A great deal has been made of the position of the palace; it has been compared by modern writers to Mount Meru, because of its pivotal location in the city plan. The plan of Jaipur is now commonly experienced as a square mandala, albeit a deformed one, of nine squares representing "the nine divisions of the universe," that is, the eight major and minor directions of space in plane and the vertical axis at the center.[28] In fact, although the triangulation of the three celestial gates and a whole host of other 'clues' scattered over the city no doubt prompt such an interpretation, it is necessary to engage in some complicated visual gymnastics in order to read the plan in this way. The internal blocks, none of which is actually square, are organized so as to make the perimeter irregular. The jagged outline is sometimes ascribed to topographical constraints which allegedly made it necessary to dislocate the northwest block to the extreme southeast and hence to transform the underlying structure. This is not the only interpretive obstacle in "seeing" the fully realized nine-part mandala. Jaipur can just as easily be construed as composed of seven or perhaps eight divisions rather than nine, depending on how one counts. For those who see seven as a significant number, another allegory, also referentially solar, comes into play. Seven was the



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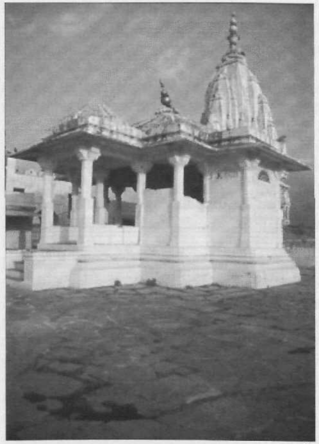
number of horses used to pull the single-wheeled vehicle of the sun god (or of Indra) through the heavens, and this reading locates the Maharaja at the center of seven blocks (perhaps as the charioteer). Confirmation of seven as numerologically signficant in the urban organization of Jaipur is provided by the seven-storied Chandra Mahal (Jai Singh's palace) as well as by the seven extant gates in the walls of the old city.

It seems beyond question that the many solar and cosmological elements and motifs expressed in the plan itself, by the observatories and by supporting iconography have stimulated subsequent readers of the city to add interpretive embellishments of their own, and that is, in itself, of great interest. Elements that are structurally or visually anomalous or discordant, even the outline of the city itself, can therefore be resolved intellectually through reference to a more comprehensive, redundantly encoded cosmological text. Nonetheless, the claims that a system of squaring representing the nine divisions of the universe or a seven-block pattern metaphorically related to the solar chariot were the underlying structures from which Jai Singh consciously departed seem, disappointingly enough, to be virtually without merit. A working drawing dating from 1725, two years before the foundation ceremony at Jaipur, which appears to be a progress report of the city under construction shows that Jaipur initially consisted of four rectangular blocks symmetrically organized with the palace block in the extreme northeast.[29] In Hindu cosmology, the northeast direction is often assimilated to the symbolism of the center in the sense that it is regarded as the upward-rising direction, the one that leads out of the terrestrial realm. Thus, for the determined, an identity can be contrived between the plan that was initially drawn showing the palace block in the upward-rising northeast and the one that emerged by the time the city was first mapped at the end of the eighteenth century showing it at the axial center. Regrettably, there is no historical documentation on how or when the four blocks developed into the final plan.

The fiction that Jaipur was built up on a system of squaring resembling, for example, the garden plan of the tomb of the Mughul emperor Humayan in Delhi (Figure 9) has been very persistent and has entered into the historical literature as fact. Tillotson reports that the archives at the City Palace Museum in Jaipur contain early drawings showing the city divided into nine equal squares and provides a stylized reproduction of them.[30] No other source including Roy (1978), who has written the most comprehensive work on the history of the city, has remarked on them, however. Tillotson may have been referring to a highly stylized diagram or chart, possibly of recent date, showing Jaipur and its tributary lands highly stylized as organized on an eight-part wheel or *mandala* pattern with the palace block and eight named gates surrounding it at the center (fig. 10).[31] This chart reproduces the administrative organization of Jaipur state, perhaps for revenue purposes as Gole (1989) has noted, but it is not in any sense a topographical map of the city nor a working drawing. It is of interest because it augments the number of gates and otherwise regularizes the city as a nine-part entity, although not one made up of square blocks. It suggests that the experience of Jaipur as a quincunx plan with nine segments may be rooted in more broadly established traditions of representation that actually stylized it in this way.

Modern understandings of Jai Singh's intentions in planning Jaipur have been extrapolated wholly through the evidence of the material record. Neither the Maharaja nor his architect ever mentioned the *sastras* or left us one word of commentary concerning Jaipur, and there is no inscriptional program associated with the city or its major structures. The historical record is thus unclear as to how Jai Singh intended to instrumentalize the internal organization of his city to recall the geometry of a cosmic pattern. In the end, the allegory of the world model was dramatized principally by the east-west axis rather by the line of the perimeter, the gates, or the organization of the blocks, and no attempt was made to overrepresent the solar trace in the form of a completed *mandala* in plane. Furthermore, as noted below, one of the most important spatial relationships set down at Jaipur is in fact partially external to its plan.

9 Garden plan of Humayun's Tomb, New Delhi
10 Reproduction of the chart from Gole
11 Sun temple of Galta
12 Wheel of the chariot from the Sun Temple, Konarak



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Jaipur as a ceremonial stage for the 'solar' king

The world pattern suggested by the plan of the city, especially by its principal axis, provided a stage on which Jai Singh could publicly produce himself as the worldly counterpart of the cosmic ruler and more explicitly as a solar king. The east-west axis originating from the Sun Gate on the east is aligned with a pilgrimage site with numerous shrines sacred to Hindus and Jains alike four miles from the city at the Galta mountain pass. In the cleavage in the eastern hills high above Jaipur at Galta lies a temple to Surya the sun god, also reputedly constructed by Jai Singh (fig. 11). The pass at Galta can be viewed from the summit of the 90-foot-high sun dial (the Samrat Yantra), the most imposing of the astronomical instruments constructed by Jai Singh at Jaipur, and is roughly on axis with it. It is above the pass at Galta that the morning sun first makes its appearance over the city of Jaipur. Each year, the solar axis from Galta across the city was activated in one of the most dramatic rituals of the Jaipur State. As a writer who witnessed it in British times put it;

"It is from here that the Image of the Sun is carried in royal state through the City in a chariot drawn by white horses once a year, at the time of the vernal equinox. His Highness the Maharaja with his Sirdars and officials, and with every accompaniment of Eastern pomp and splendor, himself joins the procession, and the whole ceremony is one of the most brilliant of the many fine scenes to be witnessed in Jaipur."[32]

According to the poet Krishnadatta, the Kachhawa Rajputs were descendant through the solar line from *cakravartins* (universal rulers). This is a matter of some importance in understanding the architectural, ritual, and political strategies Jai Singh employed to orchestrate his solar kingship. The *cakravartin* (literally, turner of the wheel) was an ancient ideal, the divine ruler who maintained temporal and moral order in the cosmos providing the model for the role of the worldly sovereign. *cakra* (wheel) is a trope for order that has been interpreted politically, ritually, and iconographically in India. In its iconographic representation as a spoked wheel, the cakra is explicitly associated with the solar cycle, the solar chariot, and solar kingship (fig. 12). *cakra* refers to the wheel of a monarch's chariot; *vartin* means turning or abiding in or ruling over a territory also called a cakra.[33] Thus the monarch as the turner of the wheel is the universal sovereign whose dominion extends as far as the wheel of the chariot reaches.[34]

The official registers of Jai Singh's daily activities at Jaipur capture him as borne through the city in his chariot on Hindu holy days,[35] and thus call forth the figure of the cakravartin. It seems beyond question that this identity was carefully cultivated. The Maharaja referred to his chariot as the Indra Vimana, the vehicle of Indra, and thereby explicitly compared himself with the tutelary god of the Indo-Aryans, the world conqueror to whose heaven virtuous kings are said to go after death. The most grandiose gesture Jai Singh made as a would-be cakravartin was the revival of ancient sacrificial rites described in the Vedas. The most dramatic of these rites was the horse sacrifice which he performed near the end of his life, probably in 1741, although other dates are sometimes given. This rite, in which a consecrated horse was set free and allowed to roam unimpeded over the king's dominion for a year, was associated with hegemony over a vast territory and thus with unchallenged authority. At the end of the year, the horse was killed and dismembered according to an elaborate protocol which required the wives or consorts of the regent to lie down beside the carcass. The unimpeded odyssey of the horse spatially deployed the temporal course of the year, and the sacrifice of the animal ritually reenacted the annual regeneration of the everlasting sun. In ancient times, the sacrifice of the horse was believed to confer the vitality of Indra on the king and otherwise to be a rite of world renewal of incomparable power.[36] The power of this sacrifice is understood through the birth story of the ideal king Rama who is said to have been brought forth to the childless king Dasaratha only after it was performed. Although the horse sacrifice is associated in legend with many of the great rulers of ancient India and even with the gods themselves-in

later periods, particularly as the Brahmin priesthood came to look on blood sacrifice of any kind as increasingly abhorrent-it was rarely performed. Thus, Jai Singh's precipitous revival of a rite that was revered in the abstract as an act of great piety but regarded in practice as anachronistic and disgusting is all the more significant. According to historical accounts, not everything went smoothly. A late nineteenth-century source in Hindi, the *Itihas Rajasthan* by Ramnath Ratru Charan, reported that after Jai Singh consecrated the horse, the animal was released near the city according to plan. However, some relatives of Jai Singh who belonged to the Kumbhani branch of the Kachhwaha Rajputs evidently waylaid the horse and thereby challenged the Maharaja's authority. Many Kumbhanis were reportedly killed in a battle with royal forces that subsequently took place.[37]

Perhaps because it was traditionally an awe-inspiring event of great sanctity and perhaps because it turned into something of a melee as well, the event was long remembered as one of the most remarkable of Jai Singh's reign. An axis mundi, called the "horse sacrifice pillar," stands in the city as an enduring reminder, but there are unfortunately no reports of the proceedings. According to Roy, the white marble statue of a horse in the temple of Kalki in the Sireh Deori Bazar in Jaipur (the only temple of its type in northern India) was installed sometime after the rites were performed (fig. 13).[38] This image is now interpreted as a commemoration of the event, but it also aligned Jai Singh, as an apparent devotee of Kalki, with yet another vision of world renewal. According to Hindu tradition, Kalki (=Kalkin), the tenth incarnation of Visnu and the only one yet to come, will one day materialize mounted on a white horse as a *cakravartin* whose mission will be to restore moral order in the world.[39]

The solar allegory and the political order of Amber State

The allegorical relationship between kingship and the solar cakra was also reproduced in a political format by the Kacchawa Rajputs. In the traditional model of Indian kingship, *cakra* referred to a political alliance between the king and a number (usually twelve) of subordinate neighboring chieftains that was regarded as a circle or a mandala.[40] The king was thus compared to the sun and the twelve allies perhaps to the solar months or divisions of the zodiac through which it must pass. Amber State was said to have been established on such a model by Jai Singh's ancestor Pritviraj in the early sixteen century. Twelve *kotris* (fiefdoms) were set up in his time with land grants to three branches of collateral kinsmen and nine of his sons, who became the twelve aristocratic houses of Jaipur.[41]

In the name of Jaipur (= the city of victory), the celestial and political orders were aligned with the identity of the Maharaja through a common trope. The divine king, of whom Indra was the archetype, was the just warrior who with conquests over forces of disorder, especially those associated with drought and darkness, insured the continuity of the cosmic cycles. The cosmological ordering that was seen as a battle won was hence closely associated with the renewal of the seasons and the return of the sun. Analogous to the eternal order secured by the gods, was the continuity of the state secured by the worldly sovereign. *jai,* the epithet attached to both the Maharaja and his city, means conquest or victory and by extension, 'everlasting.' It is often used as an exhortation meaning 'live long.' *Singh* (lion), the title assumed by the Rajput rulers, carried additional traditional associations with conquest, with unchallenged authority, and with the solar principle.

Kingship and the celestial order of Islamic astronomy

The divine city model of celestial order was Near Eastern in origin. It was diffused into India in ancient times and emerged as an allegorical plan for house, palace, temple, and town in the Hindu and Buddhist traditions. In the medieval period the Mughals reproduced it in the rigid geometry of the paradisal garden, best known as the setting for their imperial tombs (the Taj Mahal in Agra and the tomb of Humayan in Delhi are the quintessential examples). The projection of sovereign power through a celestial order as formulated in a cosmic geometry was thus a familiar narrative in the Indian landscape, realized in building traditions often seen as historically independent. Jai Singh's attempt to conjoin it with the architectural order of Islamic astronomy was by contrast completely unprecedented.

Through the vehicle of Islamic astronomy, Jai Singh reformulated his privileged link with the cosmic order and styled himself himself as an eminent and divinely inspired scientist. Making this identity visible were the astronomical instruments of startling proportions he had built at strategic locations, major centers of political or ritual authority. As already noted, the largest of the complexes were located in the palace precincts at Jaipur and at Delhi, the seat of the reigning Mughal emperor Muhammed Shah, whom Jai Singh compared in the introduction to his well-known astronomical tables, the *Zij Muhammed Shahi,* to the sun of the firmament.[42] The others were built in three of the seven holy cities of the Hindus—locations to which the Kachhawa Rajputs had been fortuitously dispatched in administrative capacities or on military campaigns: Matura, the birthplace of Krishna; Ujjain, sacred to Siva and the point from which Indian longitude was initially calculated; and Benares, also sacred to Siva, the site where ten legendary horse sacrifices were performed, and the holiest city of them all. Jai Singh had grandiose plans to built additional observatories in other large cities so that "every person" devoted to astronomy could make independent observations. If it had been carried out this scheme would have peppered North India with the demonstrable evidence of his intellectual hegemony. As it was, Jai Singh seems to have been well occupied for nearly twenty years with his architectural program. The accepted chronology places the completion of the observatories in the following order: Delhi (1724), Jaipur (c. 1734), Ujjain (c. 1734), and Benares (c. 1737).[43] The observatory at Matura, which was located in the old fort there, was completed later, perhaps a few years before the death of Jai Singh in 1743.

In the introduction to the *Zij Muhammed Shahi,* Jai Singh called his mathematical and astronomical knowledge "thorough" and "perfect." In these ways it resembled the omni-



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13 The statue of the horse in the temple of Kalkin

science of those gods from whom he claimed descent. In fact, in the same work he ascribed his singular insight in astronomical and mathematical matters to the aid of the "Supreme Artificer"[44] which, according to his own testimony, distinguished him from the greatest astronomers of all time. He criticized the work of Islamic astronomers, from whom most of his insights were actually derived, as intellectually arid and boldly attacked the Greeks, saying that along with all other astronomers they suffered "from [an] inability to comprehend the all-encompassing beneficence" of God. Hipparcus, the most famous astronomer of antiquity, he characterized as an ignorant clown; Ptolemy he wrote off as "a bat who can never arrive at the sun of truth." Jai Singh compared the celestial order to a well-ordered divine kingdom, and by implication, to his own. The lofty orbs of heaven were seen as pages in the celestial state record, the stars and "that heavenly courser the sun" as part of "the treasury of the empire of the Most High."

Jai Singh's inclination to represent his sovereign authority as the expression of a privileged intellect comparable to that of a great sage dated back to events in his childhood. When he was presented at the imperial court in Delhi for the first time in 1696 at the age of seven, the emperor Aurangzeb reportedly was impressed by his precocity and called him *sawai*, meaning one and a quarter. This was taken by Jai Singh to mean that the highest authority in all India regarded him as an intellectual giant. Subsequently he became reoccupied with public acknowledgment of his superior intellect and prowess in the sciences. For the first thirteen years of his reign at Amber, Jai Singh repeatedly petitioned the imperial court at Delhi to confer Sawai as an official title. The request was finally granted by the emperor Farrukh-siyar in 1713, six years after the death of Aurangzeb. Thereafter the Maharaja referred to himself as Sawai Jai Singh. Later he transferred the epithet to his new town, which he called Sawai Jaipur.

During the early years of Jai Singh's reign, northern India was politically fractured by wars of succession that followed the death of Aurangzeb, and Jai Singh was deeply absorbed by political and military maneuvers so as to retain control over his contracted and economically troubled kingdom. Eventually, he consolidated his power in the region, and became an influential figure at the imperial court at Delhi, but it was clear, that whatever posture he struck at home, he was no cakravartin. It was the Mughals, however fleetingly, who ruled India from sea to sea.

The Mughal emperors, who themselves used monumental architecture programs, including their lavish imperial tombs, to proclaim their political authority in India, were apt to recognize extravagant projects undertaken by their subordinates in the provinces as portents of political trouble. The building program in marble and sandstone undertaken by Jai Singh's forebears at their previous seat at Amber evidently aroused the envy of the emperor Jahangir, who saw it as a challenge to his authority.[45] By the early 1720s, the Maharaja had devised a novel strategy for making himself known beyond his own borders and identifying himself with the Mughal political and territorial order without directly contesting it. He set out to erect monuments to his own kingship throughout the realm under the cloak of science. In order to secure the permission of the imperial authorities for the first undertaking at Delhi, he appealed to the Emperor in the interest of the empire. As he wrote in the *Zij*:

"Seeing that very important affairs, both regarding religion and the administration of the Empire, depend upon these; and that in time of rising and setting of the planets, and the seasons of eclipses of the sun and moon, many considerable disagreements of a similar nature were found—he represented the matter to his Majesty of dignity and power, the sun of the firmament of felicity and dominion, the splendour of the forehead of imperial magnificence, the unrivaled pearl of the sea of sovereignty, the incomparable brightest star of the heaven of empire, whose standard is the sun, whose retinue the moon, whose lance is Mars and whose pen is Mercury, with attendants like Venus whose threshold is the sky, whose signet is Jupiter, whose sentinel is Saturn—the Emperor descended from a long race of kings, an Alexander in dignity, the shadow of God, the victorious king Muhammed Shah. May he ever be triumphant in battle."

The Delhi observatory and the Zij Muhammed Shahi

The ostensible purpose of building the Delhi observatory (c. 1724) was the compilation of a set of astronomical tables *(zij)* subsequently named the *Zij Muhammed Shahi* in honor of the reigning emperor. Virtually everything now known about the construction of the observatories is based on Jai Singh's own testimony given in the introduction added to the Delhi *zij* in later years, probably in 1740-41[46] There Jai Singh justified his building program on the grounds that the astronomical tables in common use, whether they were Hindu, Greek or Islamic, were incompatible and inaccurate. The inaccuracies were ascribed to the metal instruments then used, especially to their small size, and to deviations produced by wear and tear on their parts. He set out to replace them with larger instruments "of stone and lime of perfect stability."

Although large masonry instruments were not unknown in the world, they were confined to a few sites in the Near East and Central Asia. Very little of these remain. The observatory built at Samarkand by Ulugh Beg, a grandson of Timur, in 1428 or 1429 is widely believed to have contained instruments that served as models for some of Jai Singh's designs. The remains of a single instrument there, a giant masonry sextant originally enclosed within a circular three or four-storied structure, were discovered by the Russian archaeologist V.L.Vyatkin in 1908.[47] They recall the winged quadrants of the Samrat Yantra, but otherwise there were numerous dissimilarities, including the aforementioned circular tower. In addition, fifteenth-century sources mention that the walls of the Samarkand observatory were adorned with murals displaying mythical representations of the celestial bodies,[48] and nothing of this sort was attempted in India. In any event, since the Maharaja insisted that the design of the instruments was his own, very little can be recovered about the specific precedents for the instruments, who adapted them and oversaw their construction in India, or, if they were actually based on prototypes in the Central Asia, how detailed knowledge of them was obtained at a distance.[49]

The fact that the forms were unprecedented in India at the time quite naturally suggests that Jai Singh's astronomical program was equally innovative, but this was far from the case. Jai Singh was concerned almost wholly with the rectification of existing astronomical tables, especially those of Ulugh Beg from which, despite public claims to the contrary, his differed very little. Jai Singh's astronomy was based on a geocentric view of the universe, derived almost exclusively from the work of Ptolemy and Islamic works directly indebted to it, which was already in disrepute in Europe. It is sobering to consider, as Kaye (1918) has pointed out, that Jai Singh died exactly two hundred years after Copernicus. It is nonetheless beyond question that Jai Singh had an avid interest in the astronomy of the times and stimulated an interest in it through the observatories. He also collected and translated manuscripts on astronomy and astrology, some of which are preserved today in the archives at Jaipur, hosted foreign astronomers at his court,[50] and sent assistants to Europe to gather information-unfortunately, it turned out, from the wrong sources. It remains unclear whether Jai Singh was entirely uninformed about the scientific revolution in Europe or simply more preoccupied with astronomy as a declamatory tool.

The anachronistic nature of Jai Singh's astronomy was belied in the Indian setting by the instruments he constructed. We can only guess what went through the mind of the average Indian who was confronted with gigantic forms in bold and novel shapes; contemporary commentators still find them startling and have described them variously as ultramodern, surreal, and weird.[51] The colloquial term Jantar Mantar that came to be applied all the observatories[52] is not at all the technical term for observatory; rather, it is a phrase whose stylistic flavor is captured by the English "hocus-pocus." It is taken to be a corruption of *yantra* (a term broadly meaning 'instrument', and also applied to mystical diagrams and in astronomy to sextants) and *mantra* (incantation).[53] In ritual, yantra is a spatial representation of the divine or the occult; a mantra is its auditory form. It would therefore seem that the observatories may have been received as mystically or spiritually evocative or, as suggested below, may have reminded the Indians of ritual ground.[54]

The instruments

There were ten different types of masonry instruments found at the various observatories when descriptions of them began to be made around the turn of the nineteenth century. In addition, there were smaller metal instruments such as the astrolabe and the sextant, most of which are preserved only at Jaipur. One of the most dramatic masonry forms, the Misra Yantra (Mixed Instrument) is found only at Delhi and was probably added later by Jai Singh's son Madhu Singh (fig. 14).[55] Since there were no independent descriptions of the sites made prior to 1785, important questions remain as to which of the masonry instruments were actually constructed by Jai Singh and which were added after his time. The Jaipur observatory in particular has clearly been substantially enlarged. At least three of the instruments, the Samrat Yantra ('supreme' instrument, a sundial) which is found at all of the observatories, the Jai Prakash Yantra (the 'light of Jai' instrument, an armillary sphere) and the Ram Yantra (Rama's instrument, also a sun instrument) both of which are found only at Delhi and Jaipur are most certainly designs developed by Jai Singh and very likely the only major masonry structures actually erected by him at Delhi. In the introduction of the *Zij Muhammed Shahi* these are the three instruments singled out by Jai Singh as being "of his own invention" and in fact, the only ones mentioned at all. The three belonged to a single paradigm in another important sense. They are the only masonry instruments identified by epithets, vis., 'supreme', 'Jai's light' and 'Ram.' The nomenclature of the rest of the masonry instruments, most of which are in place only at Jaipur, is transparently derived from their form ('bowl' instrument, for example) or function ('zodiac circle' instrument). A discussion of the nomenclature as it sheds light on Jai Singh's intentions follows the description of the main instruments that appears below. A succinct summary of their functions from the perspective of the non-specialist in astronomy is also provided. It is based

14 Mixed Instrument, Delhi
15 Samrat Yantra; View showing belvedere
16 Samrat Yantra, Jaipur; View from north
17 Observatory, Jaipur; Plan



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on Kaye 1918 and Singh 1978 and 1986 as noted.

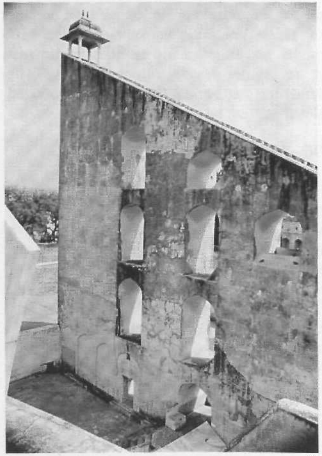
The Samrat Yantra

The Samrat Yantra (supreme instrument), is a large equinoctial dial or sundial from which solar time was read. The central portion of the instrument is a triangular gnomon, whose hypotenuse is parallel to the axis of the earth. Stairs lead to the apex of the gnomon along the hypotenuse. At Jaipur, the summit of the instrument is crowned by a *chatri* (literally, parasol) or belvedere whose four sides are oriented to the major directions and ribs to the minor ones (fig. 15). In the iconographic conventions of Hindu architecture, the chatri expressed the major axes of the entire universe. It was one of the five traditional emblems of Indian kingship[56] and an important element in the vocabulary of Rajput architecture. The cenotaphs of the Amber Rajputs were constructed as chatris. The chatri also appeared as a crowning element in Rajput palaces and forts.

The base of the Samrat Yantra lies in the plane of the local meridian and hence is oriented due north. Projecting from either side of the gnomon along the east-west axis are two giant quadrants of a circle rising like wings toward the heavens that are parallel to the plane of the equator (fig. 16). The edge of each quadrant was originally graduated in hours, minutes, and degrees. When the sun rises in the east, the shadow falls on the top of the western quadrant, gradually descending across its curvature to the midpoint of the structure when noon approaches and there is no shadow. In the afternoon, the shadow correspondingly rises across the eastern quadrant until it reaches its most distant point at sunset. The edges of the gnomon were also originally marked with scales of tangents so as to calculate the sun's declination or angular distance from the equator.

This particular instrument is found at all the observatories, but it varies in size. The dimensions here follow Kaye (1918), whose measurements have been used by subsequent writers. The Delhi structure is 68 feet high, approximately 8 feet of which lies below the ground plane. There are actually two Samrat Yantras at Jaipur one of them over four times the size of the other. The larger one, 90 feet high from its base below the earth to its apex, is in the southeast corner of the observatory precincts (fig. 17). It was described as early as 1785 by Tieffenthaler, a Jesuit missionary who traveled in India from 1743 to 1786.[57] The smaller, at a little over 18 feet in height, is roughly the size of two such instruments constructed at Ujjain and Benares. It lies off center in the northwest, as shown in the plan. The smaller instrument is not independently described by Tieffenthaler or Kaye, and the reasons why it was necessary to have two major instruments of this type in a single observatory are unknown. It may be that the smaller instrument was the original one and that the second was built later, possibly to dwarf the one at Delhi. In any event, it is hard to imagine circumstances under which the relative chronology would have been reversed. The vertical plane of the central masonry structure of the Samrat Yantra is pierced by unadorned archways which vary in number depending on the size of the instrument. Inasmuch as the style of the arches is replicated elsewhere in Rajput architecture as well as in the imperial buildings of the Mughals, it is not in itself remarkable. However, the placement of the arches recalls the composition of Hindu temples in north India whose central spires were made in the image of cosmic mountains flanked by subsidiary 'peaks.' At Jaipur, arches of identical design are repeated in the walls that enclose the observatory, recalling the encircling mountainous walls that according to Hindu mythology surround the land and the seas in concentric rings. The Ram Yantra instrument at Delhi (discussed below), is enclosed by a superstructure containing arches of identical design.

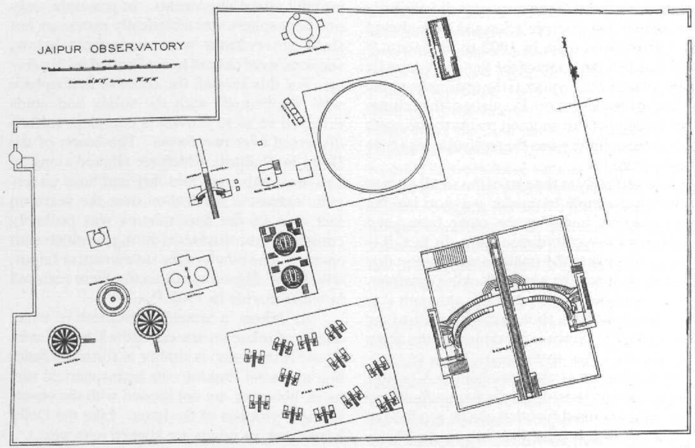
The masonry structure that supports both quadrants at Jaipur and the east quadrant at Delhi contains chambers for a sextant instrument (fig. 18). The sextant consists of two graduated 60° arcs whose surfaces face upward to the ceiling. At Delhi, the chambers were closed up early in the century because of flooding, but at Jaipur the west chamber is still accessible. Two holes projecting sunlight



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through the roof onto the instrument at midday permit the calculation of the zenith distance on the basis of the observation of the declination of the sun.

Adaptations of the Samrat Yantra

At Jaipur, the form of the Samrat Yantra has been adopted for a set of twelve smaller instruments that lie grouped immediately to the southwest of it along the southern wall of the observatory (fig.19). Aside from the Samrat Yantra, these instruments are the only ones in masonry specifically described by Tieffenthalter in 1785.[58] Since they are mentioned neither by Jai Singh in the introduction to the Zij Muhammed Shahi nor in a prior list of known instruments proper to an observatory composed by a court astronomer (c.1729),[59] they cannot be established as Jai Singh's design. This Rasi Valaya (Zodiac circle) represents each of the twelve signs of the Zodiac with a separate Samrat Yantra-like structure. The instruments are believed to have read the latitude and longitude of the sun or other celestial bodies when the particular zodiac sign was on the horizon, although it must be mentioned that the original angles of the instruments did not fully accord with this interpretation and were altered by a restoration team in 1902 to produce it.[60] Whereas the quadrants of the Samrat Yantra lie in the plane of the equator, the quadrants of the zodiac instruments lie in the plane of the ecliptic and the edge of the gnomon points to the north pole of the ecliptic when the particular sign is on the horizon.

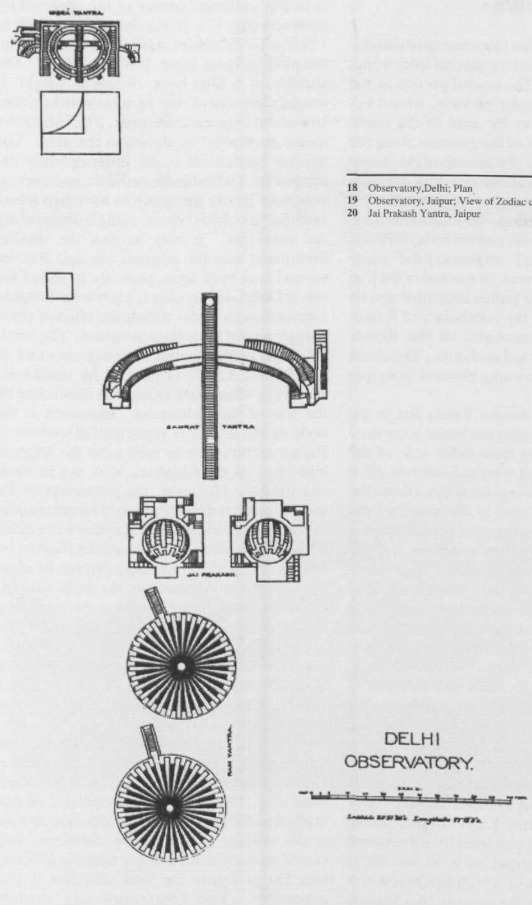
Immediately to the east of the small Samrat Yantra is a simple triangular gnomon lacking the quadrants found in the other forms and smaller in its overall dimensions. In fact, it is located so close to the small Samrat Yantra that there is no space for a west flanking quadrant. Kaye does not mention it at all, although it is partially visible in a photograph he made of the observatory.[61] Since it is oriented to the north like the two larger instruments, it has recently been interpreted as an instrument that locates the Pole Star.[62] Indeed, as it lacks quadrants, no other observational function can be ascribed to it. The two other major structures in the observatory at Jaipur, that is the Ram Yantra and the Jai Prakash Yantra, are likewise paired with formally and functionally similar instruments that are smaller in size, as noted below. The redundancies suggest experiments at reduced scales that were later produced at larger ones.

The Jai Prakash Yantra

The Jai Prakash Yantra (light of Jai instrument), seemingly named by the Maharaja after himself, consists of two mounted, concave hemispheres erected side by side that mirror the celestial sphere (fig. 20). The diameter of the hemispheres is 27 feet 5 inches at Delhi and 17 feet 10 inches at Jaipur. The markings on the surfaces of the instrument are now maintained only at Jaipur. The perimeter represents the horizon and was originally graduated in degrees. Azimuth lines, altitude circles, the tropics, and other coordinates were mapped out in the cavity. Cross wires were stretched from east to west and north to south; the shadow of the intersection of the wires falling in the cavity indicated the position of the sun in the heavens. The instrument could also be used to read the positions of other heavenly bodies by making visual alignments. In principle, only one hemisphere was technically necessary but since observations were made from below, sections were cut out to accommodate observers. For this reason, the concave hemisphere was 'duplicated' with the solids and voids reversed so as to provide a complete surface dispersed over two forms. The bowls of the Delhi Jai Prakash, which are aligned along an east-west axis, are masonry and have undergone extensive renovation over the years; in fact, one of the hemispheres was probably completely reconstructed during the nineteenth century. The bowls of the instrument at Jaipur, which are aligned north-south, were restored in white marble in 1901.[63]

At Jaipur, a second instrument in white marble of unknown date called the Kapali Yantra (Bowl Instrument) is similar in form and function to the Jai Prakash. Its hemispherical surfaces, however, are not incised with the observational trenches of the latter. Like the Delhi instrument, its bowls are aligned east-west.

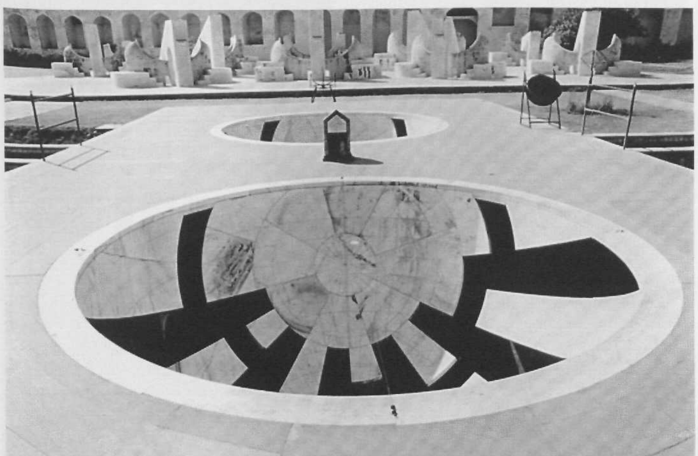
18 Observatory,Delhi; Plan
19 Observatory, Jaipur; View of Zodiac circle instrument
20 Jai Prakash Yantra, Jaipur



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The Ram Yantra

The Ram Yantra, an instrument found at both Delhi and Jaipur, is the third of the three instruments mentioned by Jai Singh in the introduction to the *Zij Muhammed Shahi.* However, it is not mentioned by name in his court astronomer's 1729 list of proper observatory instruments. This suggests that either the design was developed or this particular name attached to it sometime during the 1730s before the introduction to the *Zij* was written. The Ram Yantra consists of two large circular structures, recalling the form of the Samarkand tower, each of which has a pillar or gnomon at the center. The gigantic structures at Delhi are original to the observatory; they were restored by the Maharaja of Jaipur in 1912 (figs. 21, 22, and 23).[64] They differ somewhat in their proportions from the smaller examples at Jaipur which are modern (c. 1891) structures.[65] There are also two miniaturized examples at Jaipur of unknown date that may have been constructed as models.

At Delhi, each Ram Yantra structure is 54 feet 7-1/2 inches in diameter and 24 feet 8 inches high. The interior horizontal surface is graduated by 30 giant marble spokes of 6 degrees each interspersed with voids of the same dimension so as to form a giant wheel in plane. The spokes are raised on supports 3 feet high so that a viewer can make observations from the trenches between them. At the line of the wall the horizontal members of the floor meet 30 vertical ones that project the wheel into cylindrical form. Interior recesses between these vertical members extend the voids from the wheel upwards. Each of the recesses contains four tiered Rajput-style arches of equal dimensions. The four tiers encircling the structures each contain 30 arches. The lowermost tier is completely below the ground so that the recessed arches do not carry through to the exterior. The second tier clears the ground plane roughly at midpoint. The uppermost tiers of arches fully pierce the exterior walls. Sixteen sighting bars originally spanned each of the 30 recesses, and the graduated notches into which they were inserted remain visible on the faces of the vertical members. A massive gnomon (24 feet 6-1/2 inches high; 5 feet 3-1/2 inches in diameter)

stands at the center of the wheel. Graduated vertical lines of 6 degrees each running the entire length of the gnomon align it with solids and voids of the horizontal and vertical planes of the structure. The height of the gnomon as well as the distance from the top of the wall to the floor is equal to the distance from the circumference of the building to the center of the gnomon. As with the Jai Prakash, the two structures of the Ram Yantra are complementary forms, with the voids in one corresponding to the structural elements in the other.

At Jaipur, the Ram Yantra exhibits certain formal differences from the one at Delhi. The gnomon there is a slender iron spike. Further, the Jaipur instrument is divided into twelve sectors, rather than into thirty. In one structure the solids are 18 degrees and the voids are 12 degrees; in the complementary structure the angles of the solids and the voids are reversed. The dimensions of the structures (23 feet 1 inch in diameter and 11 feet 4 inches high) are less than half those of the instruments at Delhi.

The upper rim of the Ram Yantra structure represents the horizon and the center where the gnomon stands, the zenith. Like the Samrat Yantra and the Jai Prakash, the instrument is thus a model of the celestial sphere inverted. Immediately after sunrise and just before sunset, the shadow of the gnomon is longest and falls on the upper rim. Then, as the sun rises in the heavens, the shadow gradually descends over the wall and the floor until it reaches the gnomon at midday. In the afternoon the shadow ascends the opposite side, finally disappearing over the rim at sunset. Originally, as it moved it passed over graduations of one degree each marked on the vertical and horizontal surfaces parallel to the rim. This permitted the reading of the sun's altitude. These graduations formed concentric circles from the top of the structure to the center at the gnomon. There were also perpendicular lines of one degree which segmented the spokes and the vertical surfaces. The midpoint of the shadow of the gnomon on these lines gave the azimuth, the horizontal angle of the sun from the south point of the horizon. The graduations on the walls of the Delhi structures have disappeared, but at the Jaipur Ram Yantra, which as previously noted is modern, they have been maintained. The sighting bars are also in place at Jaipur.

The ritual order and the nomenclature of the major instruments

Till now little attention has been focused on the nomenclature of the instruments, which was not explained by Jai Singh. The names have sometimes been interpreted as allusions to historical personages, even though there is scant evidence of commemorative naming of architectural works in Jai Singh's time or thereafter. Place names in the city of Jaipur are almost entirely locational and descriptive or overtly celestial in reference (Sun Gate, Cloud Palace, Moon Palace, for example).

It is sometimes assumed that in naming the armillary sphere instrument the 'Light of Jai' the Maharaja somewhat immodestly alluded to himself. Singh asserts that Jai Singh named the Samrat Yantra (supreme instrument) after one of his chief assistants, a court astronomer and priest named Pandit Jagannath, whom the Maharaja once accorded the title of Samrat.[66] Jagannath's descendants in Jaipur evidently continue to use the title. The Ram Yantra is said to have been named after the Maharaja Ram Singh, Jai Singh's great-grandfather, a man of no particular accomplishment who ruled Amber indifferently from 1667-1688.[67] He spent almost his entire reign on duty in outposts in Assam and Afghanistan because he had antagonized the Emperor Aurangzeb, who wanted him kept out of Delhi. He was succeeded by his grandson because his only son died in a brawl at the Emperor's court in the Deccan.[68] Overall, his reign is associated primarily with a sharp decline in the prestige and influence of the state of Amber which Jai Singh spent nearly the first twenty years of his kingship repairing.[69] Given what we already know about Jai Singh's personality, it seems unlikely that he would have chosen to triangulate himself between such a figure and one of his assistants in an important architectural program at the imperial capital.

More likely, the instruments' nomenclature points to a narrative of a different kind in which the eternal cycles of the cosmos were identified with ideals of cosmic kingship. In the absence of any evidence to the contrary, the solar instrument the Ram Yantra, would seem to be, as its



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21 Ram Yantras,Delhi;
22 Ram Yantras,Delhi;
23 Ram Yantras,Delhi;

name implies, a trope for Rama, Jai Singh's most illustrious royal ancestor, rather than a sly attempt to introduce the memory of a somewhat more controversial one into the architectural fabric at Delhi. Jai Singh was eclectic in his temple patronage, but nonetheless a better known devotee of Rama than of any other deity. Described in Valmiki's *Ramayana* as learned, eloquent, the best of royal seers, Rama was a wise king who used his intellectual gifts to practical ends.[70] In this sense, he was a powerful exemplar for Jai Singh's own kingship, and thus a worthy object of the Maharaja's devotional attention. Rama was also seen as most profound evidence of the regenerative power of sacrifice, since he was born to the royal line of Ayodhya only after the horse sacrifice was performed by his father. His birth, which regenerated the solar lineage of Dasaratha, was compared to the rebirth of the everlasting sun. Rama was also the descendant of Surya, the sun god, to whom Jai Singh erected a temple at Galta. Presently, indeed, Rama is linked to Surya in the sacred geography of this pilgrimage destination; two of the principal temples there are dedicated to him. According to the narrative the Kacchawa Rajputs set forth about themselves, Jai Singh was Rama's lineal descendant and mortal reflection.

The epithet *samrat* is likewise rooted in the imagery of solar kingship and cosmic rejuvenation. According to the court poet Krishna Bhatta, who compiled a Sanskrit work on Jai Singh's reign soon after his death, Jai Singh obtained the title of samrat ('preeminent among rulers') by performing an important Vedic sacrifice, the *vajapeya*.[71] His performance of the vajapeya has come down to us in written records as one of the singular events of his reign; it was mentioned as early as 1729 in the introduction to a translation of Ptolemy's *Almagest* done for him by Pandit Jagannath.[72] Drekmeier, writing of the Vedic king, confirms that samrat, 'pre-eminent among rulers', was the title conferred on the king who performed this important sacrifice.[73] As part of the elaborate rituals of the vajapeya sacrifice, a chariot race tracing a circuit in which the sacrificer (king) was always the victor was undertaken. The chariot race was a central feature of a number of Vedic rites connected with the year and with cosmic regeneration. The race linked the annual renewal of the generative powers in the universe to the renewal of kingly authority.[74] The form of the race course evoked the cycle of the sun, as did a numerological metaphor: When the chariot was yoked, a verse was recited referring to the 27 godlings who harnessed the chariot of Indra. They corresponded to the 27 constellations in the Hindu heavens which were transited by the sun in its annual course.[75] The triumph of the king in the race corresponded to the beginning of a new temporal cycle. The boon was the everlasting sun or the renewal of the year.

The name Jai Prakash is likewise amenable to interpretation through the narrative of the solar cycle and cosmic renewal. The literal meaning of Jai Prakash is the "light of victory" or "the light of Jai," calling to mind the certain victory of the king as sacrificer in the vajapeya chariot race. The light in question would be that of the sun. As in the chariot race, the victory is its regeneration, its everlasting nature. Jai, in the person of Jai Singh, identified the sacrificer and the victor. "Jai Prakash" therefore suggests a reflexive link between the everlasting sun and the solar monarch of the everlasting state. And in fact Jai Singh is often depicted in Rajput painting with his head set against the disc of the sun

The observatories as settings for ritual action

As a corruption of the words for diagram (yantra) and incantation (mantra), Jantar Mantar suggests a popular reading of the observatories as settings for ritual action. Possibly, such a reading was provoked by the very names of the three main instruments at the observatories, with their explicit link to rites. A comparison of the design of the instruments and that of Vedic sacrificial altar suggests that the evocative paradigm may be formal as well as linguistic. Both the Jai Prakash Yantra and the Ram Yantra are reminiscent of the elements of the ritual assemblage. The Ram Yantra suggests a nearly literal interpretation of the chariot wheel over which oblations were poured into the sacrificial fire. The elevated, mounted depressions of the Jai Prakash Yantra suggest the formal geometry of the altar itself.


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The Vedic altar consisted of three firepits: a circle representing the earth, a square representing the heavens, and a semicircle representing mid-space. (Fig. 24) The firepits were arranged around a central space called a *vedi* on which the materials of the sacrifice were kept. It was a ritually inactive space in the sense that no fires burned there. The arcs running the length of the vedi can be generated from two unrealized circles; a similar exercise generates the arcs on the parallel sides. The overall geometry of the vedi can be suggested simply by reversing the figure-ground relationship of the Jai Prakash as well as its formally similar instrument the Kapali Yantra. At Jaipur, the bowls of the Jai Prakash, are positioned so that the north-south axis passes through the hemispheres and the east-west axis bisects the central void. In the hemispheres of the Delhi Jai Prakash, as well as in those of the formally similar Kapali Yantra at Jaipur, these relationships are transposed, with the main axes across the instruments running east-west.

Previous considerations of formal precedents for the instruments at the observatories have focused almost entirely on Islamic handheld instruments such as astrolabes, suggesting that Jai Singh's principal interpretive contribution was to enlarge them to a ridiculous scale in masonry and to fix them as features in a unprecedented architectural landscape, inspired perhaps by reports of similar efforts at Samarkand. The design of the Jai Prakash, for example, has been presented as a magnification of movable graduated bowl instruments from the Near East.[76] To a degree, Jai Singh's own statements in the preface to the *Zij Muhammed Shahi* lend support to the interpretation that he was concerned naively with questions of scale. Nonetheless, the contention that Jai Singh simply enlarged or amended available designs is belied by the forms themselves. There is no credible precedent on any scale for the form of the giant wheels of the Ram Yantra or for the incised bowls of the Jai Prakash, for example. The Maharaja claimed that the instruments were of "his own invention," and in some measure this seems to have been the case. Inasmuch as their design seems to incorporate a Hindu subtext of cosmic control that referred obliquely to rites both formally and linguistically, it suggests an imaginative break with the smaller instruments of the Islamic tradition rather than a reduplicative exercise. Inasmuch as there is a covert text that refers to ritual action as an instrument of cosmic control, it is a matter of interest that the observatory at Jaipur has actually served as a setting for rites associated with the passage and control of time.

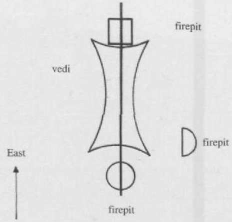
Summary and conclusions

The most innovative components of Jai Singh's building program-his city plan at Jaipur and his astronomical instruments-are thus linked to cosmic rejuvenation and the orchestration of solar kingship. The plan of the city of Jaipur expresses a cosmological ordering of the earthly kingdom through selective allusions to a cosmic plan which was quite literally duplicated elsewhere in Indianized Asia. The capital cities of the Burmese including Mandalay,[77] the temple cities of southern India such as Madurai[78] and Kandy in Sri Lanka[79] are examples of other planning attempts to replicate cosmic order in miniature. "Frozen" within a geometrical frame, the inexorable order imputed to the world of the gods could be visually apprehended as a conclusive link between the cycles of the cosmos and the authority of the worldly king. The axial urban plan was at once an expression of this order and a stage on which sovereign authority could be dramatized in ceremonies and rituals of the state, such as the marshaling of the sun from Galta at the time of the vernal equinox.

At Jaipur, the most concise form of the cosmic narrative was found in the rectilinear site plan itself, which projected the passage of solar time onto the east-west axial organization of the city. Very broadly therefore, the sovereign could be understood through the idiom of the rectilinear geometry of his capital to be the master of time as well as of space. Other measures elaborated the meanings succinctly represented by the site plan. In his discussion of the Burmese royal city, Aung-Thwin has argued that the Asian regent was the custodian of sacred time and the capital city the keeper of it. In the Burmese capitals, a water clock was kept on the north side of the main east gate, and the hours of day and night sounded at appropriate intervals by the banging of a drum: "the days and nights, weeks and months, seasons and years were calculated according to this system, controlled by and located in the capital city."[80] At Jaipur, as in other capitals of Indianized Asia, the instruments of timekeeping were located within the precincts of the celestial city on earth, but with an important difference. Here they were interpreted architecturally so as to become fixtures in the cosmography of the city itself. The link they established in the mid-space between the terrestrial world and the celestial one was further expressed by their literal functions, as well as by their rough alignment with respect to axial roadways of the city, its named gates, and the shrines at Galta. Their location within the central palace precincts identified the celestial order unambiguously and publicly with the authority of the Maharaja who measured out the hours and the minutes through instruments of his own invention. The relationship between the heavens and the earth on the one hand and the state and the celestial order on the other were woven into a gestalt of universal order through a nomenclature that stimulated memories of rites.

In Jai Singh's time eclipses were announced to the citizenry by a drum beaten beneath the chatri or belvedere on the summit of the Samrat Yantra at Jaipur.[81] The chatri was one of the emblems of kingship and as an *imago mundi* a concrete representation of universal sovereignty. The architectural vocabulary of the Samrat Yantra, with the royal arches on its vertical surface and especially its crowning parasol oriented to the major and minor directions, thus provided the backdrop for rituals of time keeping that placed the worldly sovereign at the center of temporal regulation and cosmic control.

At the present time, on the full moon day of the month of Ashadha (June-July), that is roughly at the time of the onset of the monsoon season, the pandits of Jaipur gather at the observatory to conduct rites connected with ensuring the return of the rains (figs. 25 and 26). It is not a matter of record whether these rites date from Jai Singh's time, but it seems likely that they are of some historical depth. Elsewhere in Rajasthan, similar though more perfunctory rites invoking the god Indra are

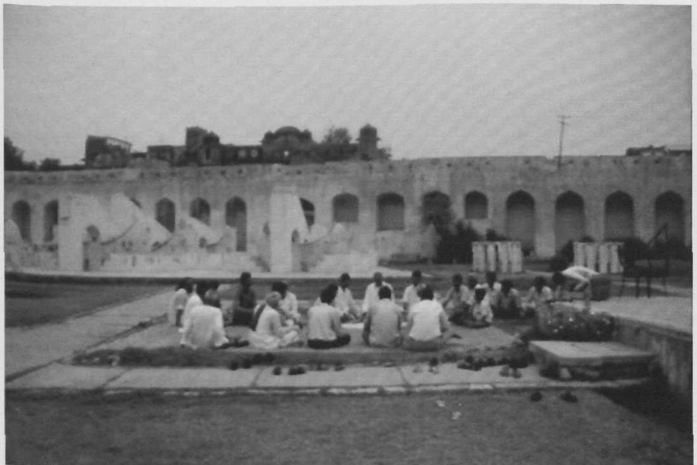


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24 The vedic altar
25 Annual summer rites at the Jaipur observatory
26 Annual summer rites at the Jaipur observatory



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customarily performed at the same time of the year in the rural villages.[82] At the observatories, the pandits first recite prayers for bountiful rains around a makeshift altar on which offerings are made and lamps are lighted. Then they proceed to the summit of the Samrat Yantra to hoist a flag at sunset that shows the direction of the prevailing winds. Winds from the north, northeast, and east at that moment are said to predict good rains and good crops, whereas winds from the south and southeast predict drought and famine. According to the Vedic literature, the god Indra vanquished the evil forces that brought on drought and eclipses with his thunderbolt. Inasmuch as Jai Singh carefully compared himself to Indra and energized his sovereign authority with the might of Indra through the rites of sacrifice, it is noteworthy that both rains and eclipses became closely associated with the functions of the observatory. It is also of interest that the marking of the passage of time at the observatory was projected in auditory form: for example in the beating of drums at eclipses and perhaps on other occasions and in the recitations by the pandits themselves. The now largely lost experience of the observatories as sound (mantra) as well as space (yantra) seems likely to have inspired the term Jantar Mantar that came to be applied to them.

As we have seen, Hindu architectural design entrapped celestial alignments in the plan form of the building or city. Earthly palaces and cities were regarded as reproductions of celestial ones that lay at a distance unseen in the realm of the gods. The Hindu temple with its central 'mountain' and surrounding seas reproduced the mythic geography of the ordered universe as a holistic icon. The earth was thus configured so as to mirror the sky. The instruments at the observatories transposed the celestial pattern onto an earthly one with special clarity, since they were uncomplicated by other programmatic considerations that were involved in the design of cities, palaces and dwellings. In all works of architecture, mirroring was an underlying design principle; at the observatories it was one and the same as the function.

On other Hindu architecture of scale especially temples, rich iconographic details were additional devices for concretizing a divinely directed order. The temple was not simply oriented to the major and minor directions; its cardinal points were commonly marked by anthropomorphic representations of the eight regents that governed them. The wheel of the chariot representing the solar cycle was a common surface motif. Other sculpture rendered celestial events or elements (the sun and the eclipse, for example) in anthropomorphic or theriomorphic form. Stylized miniaturizations of the cosmos, especially the parasol, were important elements in civil architecture as well. In this manner, celestial elements, temporal cycles, and cosmological structure were approached and understood visually through a concrete language. This cosmological structure was also apprehended ritually in the culture, especially in the sacrifice, through some of the same metaphoric devices. Thus traditional architecture layered mythically apprehended understandings of cosmic order onto that which was observationally derived.

The program of Jai Singh's observatories was unique in the Hindu experience because it set aside the iconographic subtext in architecture of scale. At the observatories, monumental architecture remained a method of apprehending cosmological order, but the program substituted divinely revealed mathematics and geometry as a privileged form of understanding.

The photographs on this work, unless otherwise noted, are drawn from the Robert D. McDougall collection in the Morris Wells Slide Library, College of Architecture, Art, and Planning. The author gratefully acknowledges the help of the Slide Library in the preparation of this work. The author also thanks Anahita Poonegar who oversaw additional photography at Jaipur in the summer of 1992 and also assisted in the collection of bibliographic materials for this work.